ANALYSIS OF THE INFLUENCE OF WIND GENERATORS ON THE QUALITY OF ELECTRICITY AT THE POINT OF CONNECTION TO THE DISTRIBUTION NETWORK

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Abstract

The lack and the high price of fossil fuels imposes the need to use renewable energy sources. The advantages of using wind energy to convert it into electricity are primarily in the inexhaustible amount of energy that is environmentally friendly, as well as in economic justification, which results in the fact that the European Union is experiencing rapid growth of wind farms [1], [2]. This paper presents the results of the analysis of the impact of a wind generator located in the area of Tutin, Republic of Serbia, on the parameters of electricity quality at the point of connection to the distribution network. The results of measurements on a wind generator were used in this paper. Cases of operation at start and stop of wind generators in low wind conditions, as well as at steady - state operating modes were analyzed.

Keywords: Wind generator, electricity quality, measurements, distribution network

INTRODUCTION

The negative effects of fossil fuels have forced researchers finding new and renewable energy sources that are both environmentally more suitable and renewable. Wind energy is a renewable energy sources and has shown very fast development in the whole World. The issue of electric power security and stability, conditions the economic, industrial and social development of a country, so that obtaining electricity from renewable energy sources represents a development interest related to increasing the share in electricity production. The functionality of the electricity system is based on technical rules that must be met by electricity producers, by consumers connected to the electricity network and by companies that operate the network. In that sense, the rules for the operation of electric power systems prescribe technical rules for the connection of wind generators (Grid Code) [3]. Constant changes in wind speed, despite modern wind turbine designs, result in the fact that installation, activation and operation of wind turbines can have a significant impact on the quality of electricity, as well as on the stability of the power system. Considering the different technical constructions of mechanical and electrical wind generator assemblies [4], the paper describes the solution of the analyzed wind generator with multi-pole synchronous generator [5] and turbine without mechanical multiplier (transmission mechanism), is attractive due to lower price, weight and significantly lower maintenance costs, with reference to two characteristic operating modes, in order to considerate possible problems that arise in practice.

CONCEPT OF WIND GENERATOR CONNECTED TO THE NETWORK

The development of wind turbine technology goes in the direction of finding new solutions for the most efficient use of wind energy by increasing the rotor diameters of the generator, as well as increasing the conversion efficiency through the growing role of energy electronic converters as an interface between the generator and the network [6]. Thus, in this case, a two-way voltage converter was used to connect wind generator to the network.

The construction of a two-way voltage converter consists of two identical converters connected in a "back-to-back" topology, with a capacitive filter in a direct intermediate circuit as a kind of interface [7]. The converter circuit

can have different solutions, it is usually a configuration with IGBT switches, where the power of the converter can be increased by a parallel connection of the IGBT module. Such a configuration provides maximum wind energy utilization, the ability to inject reactive power into the network, and compensate for reactive power in the event of a "weak grid" or system failures. A transformer can also be connected towards the network, depending on the voltage level.

By using a multi-pole synchronous generator, it is possible to avoid the use of reducers, which is a great advantage of this concept over the others. In this case, a generator ENERCON type E-40, power 500 kW was used [8]. In addition, since the entire power passes through the energy converter, this solution is excellent during disturbances in the network, limiting transient currents to a minimum.

The management of active and reactive power flows has also been improved, which makes this solution more favorable for network operators. The block diagram of the wind generator is presented in Figure 1.

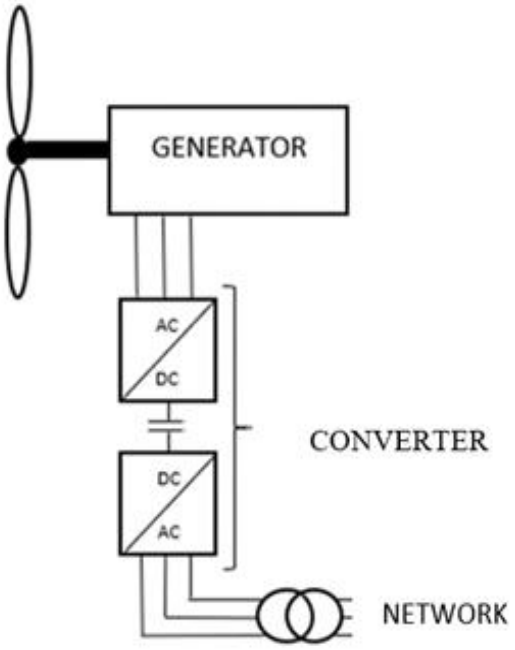


Fig. 1. *Wind generator block diagram*

Although many working conditions affect the operation of wind turbines, this paper primarily focuses on the impact on the quality of electricity. The analysis of electricity quality studies various phenomena that occur in power systems such as supply voltage variations, system asymmetries, harmonic distortions, and others. When we talk about the high quality of electricity, it mainly refers to the supply voltage quality with a precisely defined amplitude and frequency to the nonlinear nature of operation of modern electronic energy converters, higher harmonics of current and voltage are generated in the connection network, which result in the appearance of various negative effects of wind turbine operation were performed at the point of connection to the distribution network at voltage level 10kV and generated power of 0 ~ 85 kW, in order to emphasize the most unfavorable case of wind generator operation, as well as at steady-state operating modes, which means that, in this case, we selected the operating mode in which the generated power is in the interval of 100 ~ 170kW, in accordance with the standards and technical recommendations.

The best known standards in this field are IEC standards (61000, 2009) [9] and EN 50160 [10].

The measuring instrument on the basis of which the quality of electricity is determined according to the valid world standards is the analyzer of the quality of electricity.Electricity quality analyzers manufactured by Chauvin Arnoux [11], with a corresponding set of current sensors, were used for testing. The test obtained all relevant parameters (Effective voltage values, Effective values of intermediate voltages, Effective values of currents, THD of intermediate voltages, THD of currents, Active power, Reactive power, Power factor, Voltage harmonics and Current harmonics). The measuring equipment is connected directly to the low voltage side of the 0.4 / 10 kV transformer, which connects the wind generator to the 10 kV distribution network.

The summary test results are shown in Figures 2,3,4 for the first case of measurement, while for the second case they are shown in Figures 5,6,7.

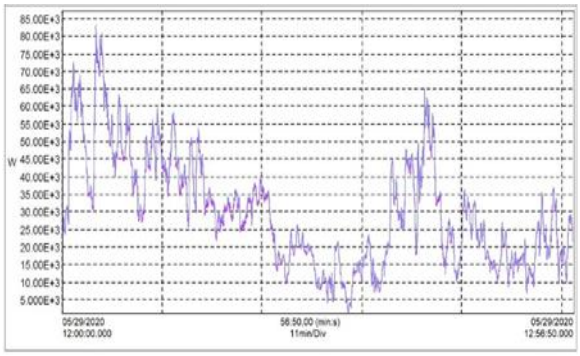


Fig. 2. *Generator active power at 0 ~ 85 kW*

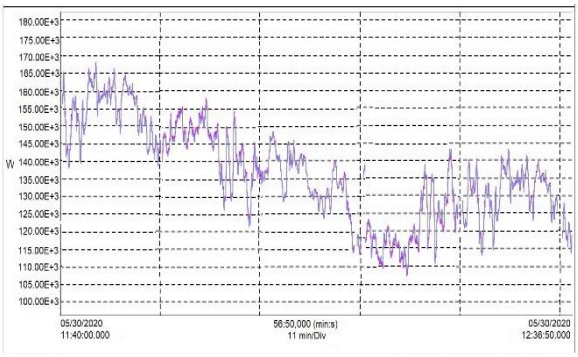
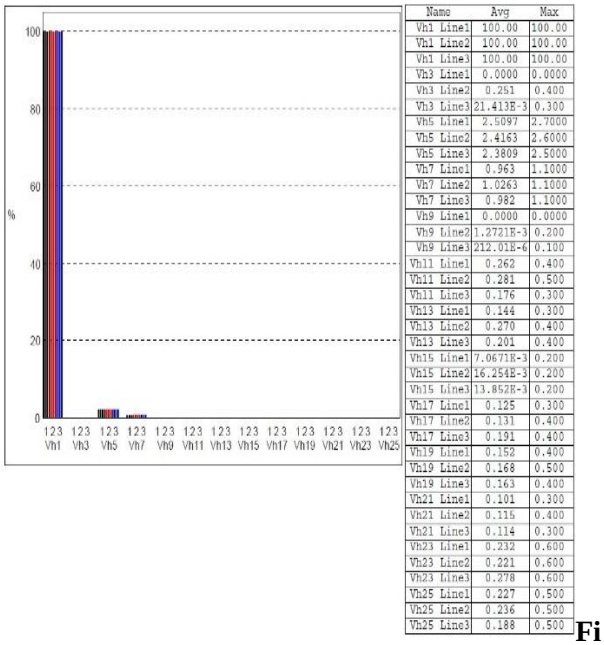
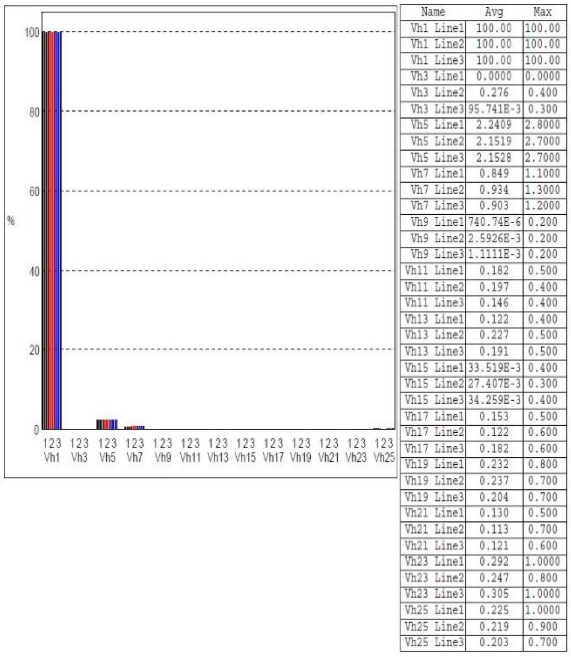


Fig. 5. *Generator active power at 100 ~ 170 kW*



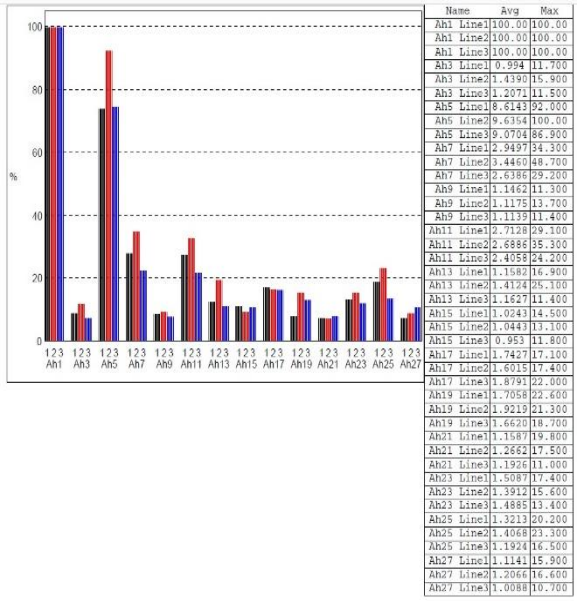
Name	Avg	Max
Vh1 Line1	100.00	100.00
Vh1 Line2	100.00	100.00
Vh1 Line3	100.00	100.00
Vh3 Line1	0.0000	0.0000
Vh3 Line2	0.251	0.400
Vh3 Line3	21.413E-3	0.300
Vh5 Line1	2.5097	2.7000
Vh5 Line2	2.4163	2.6000
Vh5 Line3	2.3809	2.5000
Vh7 Line1	0.963	1.1000
Vh7 Line2	1.0263	1.1000
Vh7 Line3	0.982	1.1000
Vh9 Line1	0.0000	0.0000
Vh9 Line2	1.2721E-3	0.200
Vh9 Line3	212.01E-6	0.100
Vh11 Line1	0.262	0.400
Vh11 Line2	0.281	0.500
Vh11 Line3	0.176	0.300
Vh13 Line1	0.144	0.300
Vh13 Line2	0.270	0.400
Vh13 Line3	0.201	0.400
Vh15 Line1	7.0671R-3	0.200
Vh15 Line2	16.254E-3	0.200
Vh15 Line3	13.852R-3	0.200
Vh17 Line1	0.125	0.300
Vh17 Line2	0.131	0.400
Vh17 Line3	0.191	0.400
Vh19 Line1	0.152	0.400
Vh19 Line2	0.168	0.500
Vh19 Line3	0.163	0.400
Vh21 Line1	0.101	0.300
Vh21 Line2	0.115	0.400
Vh21 Line3	0.114	0.300
Vh23 Line1	0.232	0.600
Vh23 Line2	0.221	0.600
Vh23 Line3	0.278	0.600
Vh25 Line1	0.227	0.500
Vh25 Line2	0.236	0.500
Vh25 Line3	0.188	0.500

Fig. 3. *Voltage content at generated power from 0 ~ 85 kW*



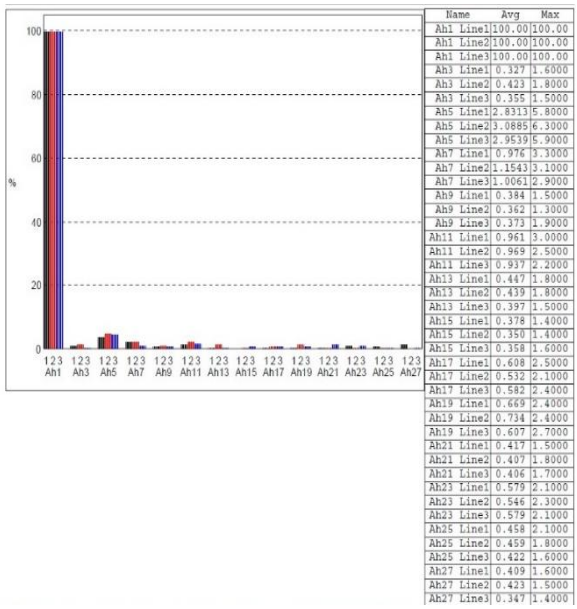
Name	Avg	Max
Vh1 Line1	100.00	100.00
Vh1 Line2	100.00	100.00
Vh1 Line3	100.00	100.00
Vh3 Line1	0.0000	0.0000
Vh3 Line2	0.276	0.400
Vh3 Line3	95.741E-3	0.300
Vh5 Line1	2.2409	2.8000
Vh5 Line2	2.1519	2.7000
Vh5 Line3	2.1528	2.7000
Vh7 Line1	0.849	1.1000
Vh7 Line2	0.934	1.3000
Vh7 Line3	0.903	1.2000
Vh9 Line1	740.74E-6	0.200
Vh9 Line2	2.5926E-3	0.200
Vh9 Line3	1.1111E-3	0.200
Vh11 Line1	0.182	0.500
Vh11 Line2	0.197	0.400
Vh11 Line3	0.146	0.400
Vh13 Line1	0.122	0.400
Vh13 Line2	0.227	0.500
Vh13 Line3	0.191	0.500
Vh15 Line1	33.519E-3	0.400
Vh15 Line2	27.407E-3	0.300
Vh15 Line3	34.259E-3	0.400
Vh17 Line1	0.153	0.500
Vh17 Line2	0.122	0.600
Vh17 Line3	0.182	0.600
Vh19 Line1	0.232	0.800
Vh19 Line2	0.237	0.700
Vh19 Line3	0.204	0.700
Vh21 Line1	0.130	0.500
Vh21 Line2	0.113	0.700
Vh21 Line3	0.121	0.600
Vh23 Line1	0.292	1.0000
Vh23 Line2	0.247	0.800
Vh23 Line3	0.305	1.0000
Vh25 Line1	0.225	1.0000
Vh25 Line2	0.219	0.900
Vh25 Line3	0.203	0.700

Fig. 6. *Voltage content at generated power from 100 ~ 170 kW*



Name	Avg	Max
Ah1 Line1	100.00	100.00
Ah1 Line2	100.00	100.00
Ah1 Line3	100.00	100.00
Ah3 Line1	0.994	11.700
Ah3 Line2	1.4390	15.900
Ah3 Line3	1.2071	11.500
Ah5 Line1	8.6143	92.000
Ah5 Line2	9.6354	100.00
Ah5 Line3	9.0704	86.900
Ah7 Line1	2.9497	34.300
Ah7 Line2	3.4460	48.700
Ah7 Line3	2.6386	29.200
Ah9 Line1	1.1462	11.300
Ah9 Line2	1.1175	13.700
Ah9 Line3	1.1139	11.400
Ah11 Line1	2.7128	29.100
Ah11 Line2	2.6886	35.300
Ah11 Line3	2.4058	24.200
Ah13 Line1	1.1582	16.900
Ah13 Line2	1.4124	25.100
Ah13 Line3	1.1627	11.400
Ah15 Line1	1.0243	14.500
Ah15 Line2	1.0443	13.100
Ah15 Line3	0.953	11.800
Ah17 Line1	1.7427	17.100
Ah17 Line2	1.6015	17.400
Ah17 Line3	1.8791	22.000
Ah19 Line1	1.7058	22.600
Ah19 Line2	1.9219	21.300
Ah19 Line3	1.6620	18.700
Ah21 Line1	1.1587	19.800
Ah21 Line2	1.2662	17.500
Ah21 Line3	1.1926	11.000
Ah23 Line1	1.5087	17.400
Ah23 Line2	1.3912	15.600
Ah23 Line3	1.4885	13.400
Ah25 Line1	1.3213	20.200
Ah25 Line2	1.4068	23.300
Ah25 Line3	1.1924	16.500
Ah27 Line1	1.1141	15.900
Ah27 Line2	1.2066	16.600
Ah27 Line3	1.0088	10.700

Fig. 4. *Currents content at generated powers* 0 ~ 85kW



Name	Avg	Max
Ah1 Line1	100.00	100.00
Ah1 Line2	100.00	100.00
Ah1 Line3	100.00	100.00
Ah3 Line1	0.327	1.6000
Ah3 Line2	0.423	1.8000
Ah3 Line3	0.355	1.5000
Ah5 Line1	2.8313	5.8000
Ah5 Line2	3.0885	6.3000
Ah5 Line3	2.9539	5.9000
Ah7 Line1	0.976	3.3000
Ah7 Line2	1.1543	3.1000
Ah7 Line3	1.0061	2.9000
Ah9 Line1	0.384	1.5000
Ah9 Line2	0.362	1.3000
Ah9 Line3	0.373	1.9000
Ah11 Line1	0.961	3.0000
Ah11 Line2	0.969	2.5000
Ah11 Line3	0.937	2.2000
Ah13 Line1	0.447	1.8000
Ah13 Line2	0.439	1.8000
Ah13 Line3	0.397	1.5000
Ah15 Line1	0.378	1.4000
Ah15 Line2	0.350	1.4000
Ah15 Line3	0.358	1.6000
Ah17 Line1	0.608	2.5000
Ah17 Line2	0.532	2.1000
Ah17 Line3	0.582	2.4000
Ah19 Line1	0.669	2.4000
Ah19 Line2	0.734	2.4000
Ah19 Line3	0.607	2.7000
Ah21 Line1	0.417	1.5000
Ah21 Line2	0.407	1.8000
Ah21 Line3	0.406	1.7000
Ah23 Line1	0.579	2.1000
Ah23 Line2	0.546	2.3000
Ah23 Line3	0.579	2.1000
Ah25 Line1	0.458	2.1000
Ah25 Line2	0.459	1.8000
Ah25 Line3	0.422	1.6000
Ah27 Line1	0.409	1.6000
Ah27 Line2	0.423	1.5000
Ah27 Line3	0.347	1.4000

Fig. 6. *Currents content at generated powers* 100 ~ 170kW

RESULT OF MEASUREMENT AND ANALYSIS

The results obtained by measurements on the transformer through which the wind generator is connected to the 10 kV distribution network, showed the following:

- all recorded maximum mean values of higher voltage harmonics are within the prescribed standards, both in case of starting and stopping of wind generators at low wind speeds with generated power of 0 ~ 85 KW, and under steady-state operating conditions with generated power of 100 ~ 170 KW.

- some of the values of the recorded maximum mean values of higher current harmonics were above the limits prescribed by the valid standards in cases of start and stop, as well as at low wind speeds, at generated power of 0 ~ 85 KW, while at operating conditions at generated power of 100 ~ 170 KW, the values of the currents of the current harmonics were within the permitted limits.

CONCLUSION

Generated power from wind energy system is always fluctuating due to the fluctuations in the wind. Although wind turbine manufacturers in the technical documentation, among other things, provide data related to the quality of delivered electricity, it is still necessary to measure the parameters of electricity quality at the point of connection of wind turbines to the transmission network in order to assess compliance with the relevant regulations defined in the network rules of the transmission system operator.

In addition to the results of the analysis of the impact of a particular wind turbine on the quality of electricity on the transmission network, this paper aims to indicate the way the wind turbine works, in order to set technical recommendations which are given when connecting wind turbines to the distribution network.

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